Bootsole

Silviculture Resource Report

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Introduction

This report describes existing and desired conditions of the silviculture resources within the Bootsole project area and the direct and indirect effects on these resources from implementing the Bootsole Project. It also documents that there would be no significant negative effects on silviculture resources, and therefore, no extraordinary circumstances related to these resources, resulting from implementation of the Bootsole Project.

The Bootsole Project was designed to: improve the growth and vigor of forest stands making them more resilient to drought stress, insect infestation, and disease outbreaks; reduce surface, ladder, and canopy fuels to reduce the size, intensity, and severity of fires within the Bootsole project area and increase the resilience of stands to wildfires; and to reduce conifer densities in aspen stands and meadows to promote vigorous, healthy aspen stands and meadow systems that can support diverse wildlife and plant species (see project need).

The indicators of stand resilience and habitat restoration that are used to describe the effects of the Bootsole Project on forest vegetation are: trees per acre, basal area, stand density index, and species composition. Canopy cover, quadratic mean diameter, and California Wildlife Habitat Relationship habitat type are stand structure and landscape heterogeneity indicators that are also presented in this report. Silviculture indicators are described in the section of this report titled, Indicators for Assessing Effects.

Fire and fuels indicators demonstrating resilience to wildfire are analyzed in the Bootsole Fire and Fuels Report (see Project Record). Considerations of stand conditions and resiliency in relation to future climate trends are discussed in the Evaluation of stand conditions with respect to forest insects and disease within the Bootsole project, Plumas National Forest (FHP Report NE20-02), also available in the Project Record

Summary of Effects

Implementation of the Bootsole Project would have no significant negative effects on the silviculture resources within the project area. Therefore, there would be no extraordinary circumstances related to silviculture resources resulting from implementation of the Bootsole Project. A comparison of stand conditions at time of inventory in Fall 2020 and following implementation of the Bootsole Project is provided in Table 1.

Implementation of the thinning and prescribed burning treatments planned in the Bootsole Project would result in progress toward meeting desired conditions for silviculture resources throughout the project area. Reductions in stand density as evidenced by reductions in trees per acre, basal area, and stand density index would make stands more resilient to drought, insects, disease, and wildfire. Treatments in eastside pine stands would be most effective at achieving stand densities necessary to sustain healthy forests during drought conditions. Treatments would be effective at shifting the species composition to a greater percentage of drought-tolerant, fire-resistant pine resulting in a landscape more resilient to drought and wildfire. The average diameter of trees, as measured by the quadratic mean diameter (QMD), within the project area would increase with the removal of small trees. Canopy cover would be reduced in some areas resulting in reduced probability of stand-replacing crown fire. Restoration of aspen and meadow communities would not only restore the valuable ecosystem services they provide but would also increase diversity on the landscape. Treating conifer stands would also increase landscape level diversity as measured by California Wildlife Habitat Relationship (CWHR) habitat type. Currently, the majority of the project area is composed of stands with an average tree size of between six and ten inches in diameter at breast height (4.5 ft, DBH), size class 3, and 40-59% canopy cover, canopy class moderate (M). Following treatment, conifer stands would have an average tree size of between 11-15 inches DBH and canopy covers ranging from 23-60%. Stands in habitat type 3M would transition to types 4S, 4P, 4M, and 4D.

Currently stands within the project area are over stocked with high densities of white fir that has established in pine stands in the absence of fire suppression but is growing at the lower end of the precipitation range favorable for its growth. Stand densities are above levels necessary to maintain forest health in times of drought. As a result, white fir in the project area has experienced moderate levels of insect- and disease-related mortality during drought years. Abundant small-diameter white fir and standing dead and downed white fir are responsible for high levels of surface, ladder, and canopy fuels levels within the project area. Modeled fire effects indicators suggest that if a wildfire started within the project area during 90^{th} percentile fire conditions during the summer to fall fire season, much of the area would experience crown fires with high levels of mortality. The project area contains aspen stands and meadows that have experienced conifer encroachment and are at risk of being lost from the project area landscape.

If the project were not implemented, mortality related to drought, disease, and insects would continue to occur as well as recruitment of shade-tolerant species. Stands would remain dense, particularly in the smaller diameter classes in terms of trees per acre, basal area, and stand density index (Table 1). Forest health would continue to decline and additional episodic mortality would be expected in times of drought and insect infestation; following these events down woody material would accumulate contributing to the surface fuel layer. As the canopies of stands become increasingly dense, and surface and ladder fuel loads increase, stands would be less resistant to wildfire and anticipated fire behavior and effects would become more severe. These factors would contribute to an increase in the probability of stand replacement in the event of a wildland fire. Continued conifer encroachment in aspen stands and meadows would further reduce the size of these diverse vegetation communities on the landscape. The project area would continue to be dominated by closed-canopy, early-seral forested stands. These stands, best characterized by CWHR size class 3 and canopy density class M, contribute to landscape homogeneity due to their abundance and connectivity.

Table 1. Values of indicators of stand structure and resilience, averaged across treatment and stand type, at time of inventory (before treatment) and following implementation of the Bootsole Project (after treatment).

Stand Types	Time Relative to Treatment	Trees per Acre	Basal Area (ft^2/acre)	Stand Density Index	Quadratic Mean Diameter (in)	Canopy Cover (%)	CWHR*
Mechanical Thinning in Eastside Pine	Before	674	192	327	8.6	50	3M
	After	74	69	99	15.4	23	4S
Mechanical Thinning in Sierran Mixed Conifer	Before	1082	182	322	6.4	51	3M
	After	185	131	205	11.5	41	4M
Mechanical Thinning in Aspen	Before	2119	191	392	4.8	48	2M
	After	1426	84	190	3.9	28	2P
Mechanical Fuels Thinning	Before	508	147	261	8.9	42	3M
	After	117	113	180	13.8	36	4P
Hand Thin California Spotted Owl PAC	Before	685	243	444	8.1	60	3D
	After	347	231	397	11.1	60	4D

*CWHR = California Wildlife Habitat Relationship, a classification of forested habitat using quadratic mean diameter (QMD) and percent canopy cover, where: size class 2 = QMD of 1-5.9”, size class 3 = QMD of 6.0-10.9”, size class 4 = QMD of 11.0-23.9”, and size class 5 = QMD of 24” and greater; and where canopy closure S = sparse or 10-24%, P = open or 25-39%, M = moderate or 40-59%, D = dense or greater than or equal to 60%.

Affected Environment

Existing Condition

The Bootsole Project is located within the Last Chance Management Area of the Plumas National Forest. Nearly all timbered areas within the management area have been harvested in the past, due to railroad logging (USDA 1988).

Historically, the project area was dominated by fire-resistant, shade-intolerant eastside pine stands (Cluck 2020). Fuel levels and species less resistant to fire, such as white fir, were maintained at low levels primarily by small (100’s to 1,000’s of acres), lightning-ignited, surface fires that occurred with an average return interval of 30 years (LFRA 2005).

Presently, the Bootsole project area is primarily comprised of upland eastside pine stands with meadows and aspen stringers, or narrow, connected aspen groves that follow the riparian corridor. Aspen is located both in upland and lowland meadows and riparian areas. There are infrequent Sierran mixed conifer stands at the highest elevations and northwestern portion of the project area. Dominant conifer vegetation within the project area includes Jeffrey and ponderosa pine with mixtures of white fir, sugar pine and incense cedar at higher elevations, and lodgepole pine in lower, moist areas. Photos 1-8 illustrate the existing condition of representative stands in the Bootsole project area.

The absence of fire during the last century has allowed white fir to become established throughout the project area. Over time, dense fir regeneration beneath older stands of shade-intolerant pine has led to a shift in species composition in most stands from primarily shade intolerant pines to a mix of pine and shade tolerant white fir. Robust fir regeneration and growth has led to many of the stands within the Bootsole project being at or above desired stocking levels. These overstocked stands have exhibited elevated levels of tree mortality, caused by bark beetles during and after periods of drought, and contain high numbers of standing and down dead trees. Mortality combined with high stand density has resulted in heavy fuel loading in some areas and a corresponding increase in potential fire behavior (Cluck 2020).

Encroachment of shade-tolerant conifers on aspen stands is resulting in decreased size and health of these unique habitats. Aspen trees are experiencing increased competition for light, water, and nutrients which is impacting stand vigor and new growth. Aspen communities are particularly important for supporting diverse wildlife and plant communities and stands with dense conifers are at high risk of losing their ability to sustain diversity. Meadows are similarly being invaded by lodgepole pine and white fir, resulting in decreased meadow sizes and leading to the decline of meadow communities on the landscape.

Current stand densities range from approximately 200 trees per acre to over 1,000 trees per acre in eastside pine and sierran mixed conifer stands with the highest densities in areas with abundant small diameter lodgepole pine. Sierran mixed conifer stands are more dense on average (1,082 trees per acre) than eastside pine stands (674 trees per acre), although the basal area is greater in eastside pine stands because of larger trees on average (Table 1). The average densities, as a function of tree size, across sample stands of each forest type are shown in Figure 1. Large, legacy Jeffrey pine are present in both eastside pine and Sierran mixed conifer stands as well as in aspen areas. Occasional incense cedar are present in Sierran mixed conifer stands but too few to be represented in Figure 1. The stem density in aspen stands ranges from near 375 stems per acre to over 3,000 stems per acre and averages close to 2,000 stems per acre (Table 1). High stem densities and small average tree size in aspen stands are attributable to high densities of both quaking aspen and lodgepole pine. In some moist areas and adjacent to meadows, lodgepole pine density in thickets of small diameter trees averages over 4,000 trees per acre. With the exception of areas identified for aspen restoration, the project area would be characterized as California Wildlife Habitat Relationship (CWHR) type 3M (trees 6-10.9 inches diameter with between 40-59% canopy cover) or 3D (trees 6-10.9 inches diameter with between greater than 60% canopy cover) in the California Spotted Owl (CSO) Protected Activity Center (PAC).

Photo 1: Pine stand with ladder fuels.

Photo 2: Dense white fir-dominated stand.

Photo 3: Sierran mixed conifer stand at higher elevation.

Photo 4: North facing Sierran mixed conifer stand.

Photo 5: Aspen growing in conifer understory.

Photo 6: Upland aspen stand.

Photo 7: Conifer encroachment in meadow.

Photo 8: Lodgepole pine bordering meadow.

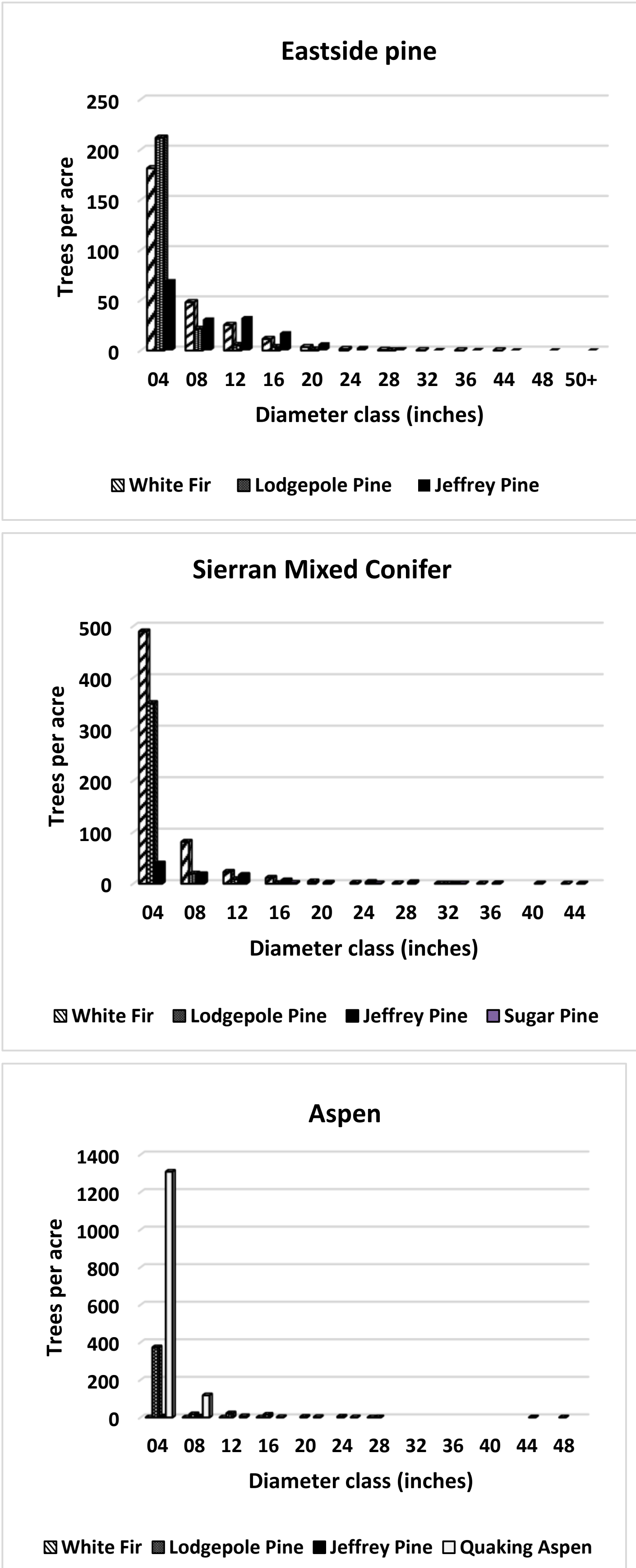


Figure 1: Diameter distribution of trees per acre by species for eastside pine, Sierran mixed conifer, and aspen stands in the Bootsole project area at the time of stand inventory in 2020.

Desired Condition

Consistent with the Region 5 Ecological Restoration Leadership Intent to increase forest resilience through treatments (including prescribed fire and thinning), the desired condition for forest stands withing the Bootsole Project is stands that are more resilient to drought, insects, disease, and wildfire. The desired conditions for restored aspen stands and meadows within the project area reflects the Plant and Animal Community Diversity Goal for Aquatic, Riparian, and Meadow Ecosystems and Associated Species of the Sierra Nevada Forest Plan Amendment (SNFPA) Final Supplemental Environmental Impact Statement (FEIS) Record of Decision (ROD) (USDA 2004) to maintain and restore the species composition and structural diversity of plant and animal communities in riparian areas, wetlands, and meadows to provide desired habitats and ecological functions.

The SNFPA FEIS ROD (USDA 2004) provides the primary guidance for achieving the Desired Conditions for silvicultural resources in the Standards and Guidelines for fire and fuels management, mechanical thinning treatments, species composition, and stand altering activities in CSO PACs. These are as follows:

- Strategically place fuels treatments across the landscape to interrupt fire spread and achieve conditions that result in stand densities necessary for healthy forests during drought conditions.
- For all mechanical thinning treatments specifically designed to meet objectives for treating fuels and/or controlling stand densities, design projects to retain all live conifers 30 inches DBH or larger.
- For mechanical thinning treatments specifically designed to meet objectives for treating fuels and/or controlling stand densities in mature forest habitat (CWHR types 4M, 4D, 5M, 5D, and 6) outside WUI defense zones: 4M = 11-23 inches DBH M = 40-59% canopy cover.

  • Design projects to retain at least 40 percent of the existing basal area. The retained basal area should generally be comprised of the largest trees.

  • Where available, design projects to retain 5 percent or more of the total treatment area in lower layers composed of trees 6 to 24 inches DBH within the treatment unit.

  • Design projects to avoid reducing pre-existing canopy cover by more than 30 percent within the treatment unit. Percent is measured in absolute terms (for example, canopy cover at 80 percent should not be reduced below 50 percent.)

  • Within treatment units, at a minimum, the intent is to provide for an effective fuels treatment. Where existing vegetative conditions are at or near 40 percent canopy cover, projects are to be designed remove the material necessary to meet fire and fuels objectives.
- For mechanical thinning treatments specifically designed to meet objectives for treating fuels and/or controlling stand densities outside defense zones in the eastside pine type: in mature forest habitat (CWHR types 4M, 4D, 5M, 5D, and 6), design projects to retain 30 percent of the existing basal area. The retained basal area should be generally comprised of the largest trees. Projects in the eastside pine type have no canopy cover retention standards and guidelines.
- Promote shade intolerant pines (sugar and Ponderosa) and hardwoods.

- Within California spotted owl PACs located outside the WUI, limit stand-altering activities to reducing surface and ladder fuels through prescribed fire treatments. In forested stands with overstory trees 11 inches DBH and greater, design prescribed fire treatments to have an average flame length of 4 feet or less. Hand treatments, including handline construction, tree pruning, and cutting of small trees (less than 6 inches DBH), may be conducted prior to burning as needed to protect important elements of owl habitat.

- At either the landscape or project-scale, determine if the age class, structural diversity, composition, and cover of riparian vegetation are within the range of natural variability for the vegetative community. If conditions are outside the range of natural variability, consider implementing mitigation and/or restoration actions that will result in an upward trend. Actions could include restoration of aspen or other riparian vegetation where conifer encroachment is identified as a problem.

Additional guidance is provided in the 1988 Plumas National Forest Land and Resource Management Plan (LRMP). The general fire and fuels management direction relevant to actions proposed in the Bootsole Project is to adjust silvicultural methods to biological requirements. The following Standards and Guidelines from the LRMP apply:

- Conifer: Emphasize control of competing vegetation in plantations.

- Convert "off -site" white fir stands to pine (white fir stands that have or have had ponderosa pine/Jeffrey pine overstory, that generally have poor vigor, and that are infected by Fomes annosus), i.e., *Heterobasidion occidentalis*, or Heterobasidion root disease).

Environmental Consequences

Indicators for Assessing Effects

Trees per Acre

The number and distribution of trees per acre (TPA) by diameter class is an important unit of measure because it shows the effect of treatments on different size trees. Data from natural stands (Dunning and Reineke 1933) indicates that for well-stocked, second-growth 100- to 150-year-old mixed conifer stands, the number of trees per acre range from 71 to 165. However, the desired trees per acre in treatment units would be lower to ensure effectiveness of the treatments for a 20-year (or longer) period. Estimates of stand densities of pine-dominated and mixed-conifer forests pre-fire suppression range from 28-65 trees per acre (Taylor 2004, North et al. 2007).

Basal Area

Basal area (BA) is the cross-sectional area of all stems in a stand measured at breast height and expressed per unit land area. Basal area per acre is commonly used as a measure of stand density. For eastside pine stands, bark beetle related mortality is expected to occur at basal areas over 150 square feet per acre (Oliver 1995) and basal areas of less than 125 square feet per acre are suggested to reduce tree mortality during droughts and high bark beetle population pressure (Egan et al. 2016). In a study of true fir stands, plots with 200 square feet per acre or more basal area experienced the bulk of the insect-related mortality (Oliver 1998). Basal areas below 200 would be recommended in Sierran mixed conifer stands in the project area, to reflect the species composition (Powell 1999).

Stand Density Index

The concept of stand density index (SDI) was first developed for even-aged stands by Reineke (1933) to compare the density of stocking of various stands. If the SDI of fully stocked or normal density stands is known, then calculating SDI for stands of interest provides an estimate of the proportion of full stocking (Wenger 1984). Silviculturists use SDI as an index of competition in forest stands (Shaw 2006). The range of recommended SDI to sustain forest health during drought conditions in the Bootsole project area is 20-40 % of maximum SDI or 90-150 for pine-dominated stands and 115-185 for mixed pine/fir stands (Cluck 2020), although high levels of insect-induced mortality have occurred in white fir during drought at 20% of maximum SDI when growing under conditions similar to those in the Bootsole Project (Cochran 1998).

Species Composition

Species composition is measured by calculating the proportion of shade-tolerant to shade-intolerant species pre- and post-treatment in terms of trees per acre and basal area. Residual species composition post-treatment provides the future seed bank. Forests in the eastern Sierra where the Bootsole Project is located were historically dominated by shade intolerant, drought and fire-resistant species such as yellow pine (Jeffrey and ponderosa), with shade-tolerant species being restricted to more mesic, north facing aspects (Safford and Stevens 2017). Treatments that increase the percentage of pine species in mixed conifer forest would makes stands more resilient to drought and fire.

California Wildlife Habitat Relationship (CWHR) Habitat Type

CWHR is a composite of quadratic mean diameter (QMD) and canopy cover that illustrates the effects of treatments on stand structure. It is also an indicator of landscape heterogeneity.

Quadratic Mean Diameter

Quadratic mean diameter (QMD) is the measure of average tree diameter conventionally used in forestry, in place of the arithmetic mean diameter. QMD is the diameter of the tree of average basal area. Compared to the arithmetic mean, QMD assigns greater weight to larger trees and is always greater than or equal to arithmetic mean for a given set of trees.

Percent Canopy Cover

Percent canopy cover is a measure of the density of the forest canopy. Stand percent canopy cover is the percentage of the ground area that is directly covered by crowns from trees greater than 6 inches DBH. This measure accounts for overlap of tree crowns and would be the opposite of the percent open sky visible when looking upward through the canopy.

Methodology

The effectiveness of proposed treatments at achieving the desired conditions for silviculture resources were modelled using Forest Vegetation Simulator (FVS), a geographic growth and yield model. Stands were inventoried in 2020 and thinning treatments were scheduled in 2022. Prescribed burning was simulated in the spring one year post thinning, except for the owl PAC where piles were burned in 2024 followed by under burning in 2025. Stand attributes at the time of inventory were calculated by the model and growth was projected for 20 years post treatment.

Alternative 1 – Proposed Action

Direct and Indirect Effects

Thinning treatments would directly affect stand conditions, including the number of trees per acre, basal area, stand density index, quadratic mean diameter, and percent canopy cover; and indirectly affect CWHR habitat type.

Implementing thinning treatments proposed by the Bootsole Project would move all silviculture indicators toward the desired conditions for all stand types. Stands would be more open with fewer ladder fuels and larger diameter trees on average. Species composition would shift toward shade-intolerant, fire- and drought-resistant pine. Reduced competition for light water and nutrients would enhance the growth of individual trees. Forest health would improve and stands would be more resilient to drought, insects, disease, and wildfire than prior to thinning.

Mechanical thinning in eastside pine and Sierran mixed conifer areas would employ variable density thinning (VDT). VDT would promote a more desired mixture of tree species (increased proportion of fire-resistant species) and sizes as well as structural diversity (a mixture of clumps of trees, openings, and matrix) that provides for improved forest health (increased tree and stand vigor) and a variety of wildlife elements while creating a fire resilient stand (decreased canopy continuity and the reduction of surface and ladder fuels). Larger legacy trees would either be stand-alone trees heavily thinned around or incorporated into residual clumps. When selecting trees for removal, preference would be given to poor vigor, diseased, and damaged trees.

Removing conifers where they have encroached into aspen stands and meadows would restore species composition and structural diversity to these vegetation types allowing them to provide desired habitats and ecological functions. Landscape level diversity would be improved through aspen and meadow restoration in addition to increased diversity of CWHR habitat types within conifer stands where stands currently classified as habitat type 3M would transition to types 4S, 4P, 4M, and 4D. Effects of treatments are shown in Table 2 and detailed by treatment and forest type below.

Prescribed fire treatments following thinning would reduce surface fuels and the number of trees per acre by causing fire-induced mortality primarily in the 1-to-10-inch diameter classes and some mortality in the 10-to-20-inch diameter classes (future snags). Mortality in the larger diameter classes may occur as the result of torching and/or delayed conifer mortality as a result of fire-damage and subsequent bark beetle attack. Overstory canopy is usually not affected by underburning, although torching of individual or small groups of trees can occur where high surface fuel concentrations and ladder fuels occur together. Localized torching from underburning would provide some small openings in the overstory where shade-intolerant species may become established and grow, depending upon the opening size. Prescribed burning would not preferentially remove unhealthy trees as would the thinning treatments.

Although not accounted for by modeling, it is expected that over time, trees per acre would increase due to the establishment of natural regeneration. It would be expected that under optimal conditions shade-intolerant trees species would become established throughout due to open canopy conditions and more shade-tolerant tree species would become established in favorable microsites (e.g., north side of residual tree boles).

Mechanical Thin Eastside Pine

Thinning stands to retain 30 percent of the existing basal area with the retained basal area being generally comprised of the largest trees, would reduce the number of trees per acre, basal area and stand density index to levels recommended to sustain forest health during drought conditions. Prescribed fire following thinning would be expected to result in mortality of some small diameter trees. The values of TPA, BA, and SDI following treatment would be within the range of historic, pre-fire suppression estimates for these metrics in pine-dominated forests in California (Taylor 2004, North et al. 2007); the resultant diameter distribution would be characteristic of a forest dominated by shade-intolerant species following episodic recruitment (Figure 2), although some white fir would be retained in areas to meet a residual basal area target of 30%. This diameter distribution is characteristic of fire-dependent pine species.

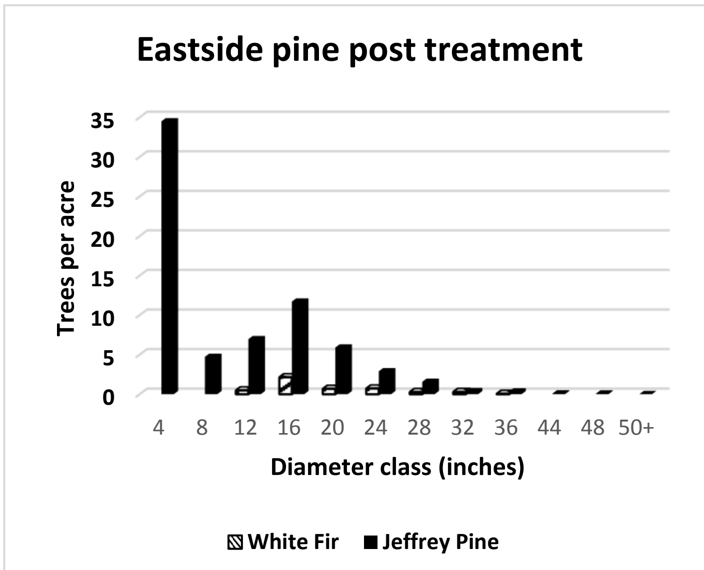


Figure 2. Distribution of trees per acre by diameter class and species for eastside pine stands in the Bootsole project area following treatment.

Treatments would shift species composition toward drought tolerant, fire-resistant pines making stands more resilient to drought and wildfire (Figures 2 and 3). Prior to thinning the majority of stems in eastside pine stands were of white fir and lodgepole pine. Lodgepole pine contributed to a small proportion of basal area and was primarily small diameter thickets growing in low elevation, moist areas. Nearly all of this small diameter lodgepole pine would be removed from these areas or would be killed by prescribed burning, and therefore, the remaining portion is not represented in Figures 2 and 3. Following treatment stand density and basal area would be dominated by Jeffrey pine with a smaller component of white fir 12 inches DBH and above.

Stands would be made up of larger trees, on average, that would be more resilient to fire. Canopy cover would be reduced and as a result the probability of crown fire spreading in treated stands would decline. CWHR type would change from 3M to 4S immediately after treatment and would transition to 4P five years after thinning with increasing canopy cover. The effects of treatments would be expected to last at least 20 years. A visualization of the effects of thinning on eastside pine stands is shown in Figure 4.

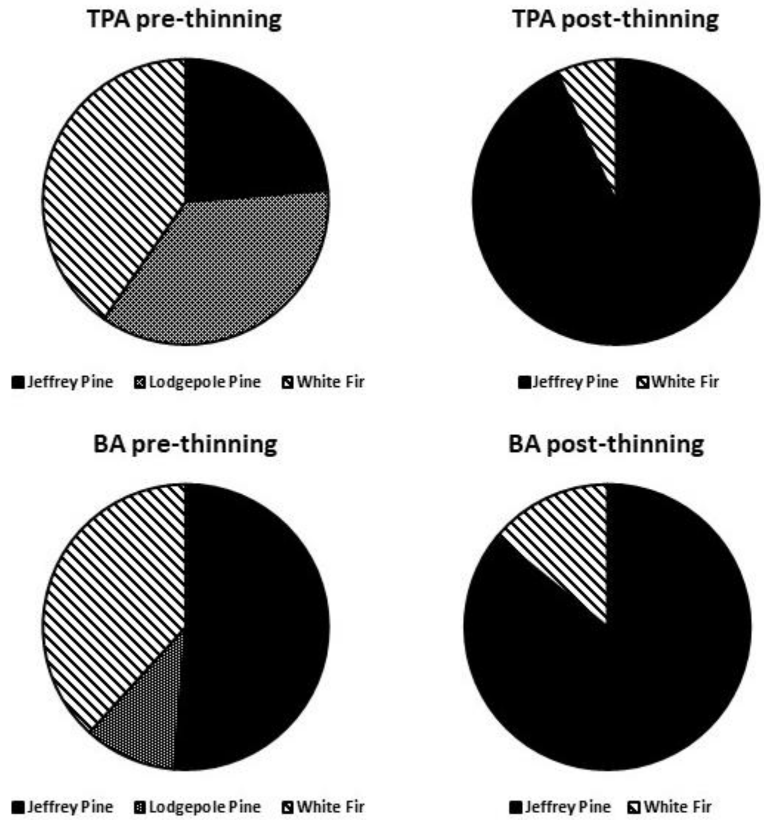


Figure 3. Proportion of trees per acre and basal area (ft2/acre) by species in eastside pine stands within the Bootsole project area pre- and post-treatment

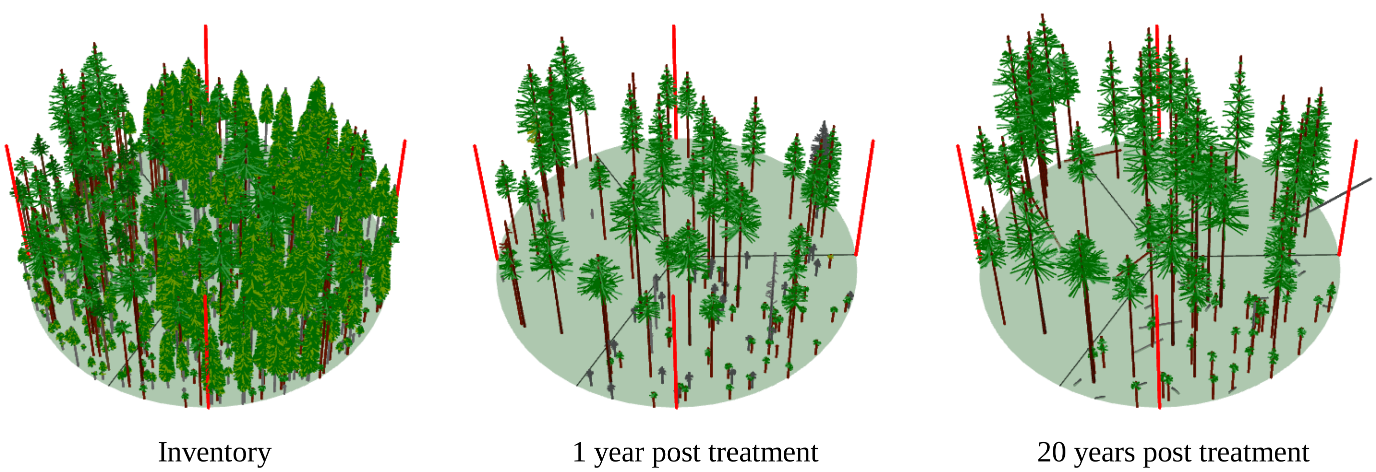


Figure 4. Visualization of eastside pine stand structure at the time of inventory, one year post treatment, and 20 years post treatment.

Mechanical Thin Sierran Mixed Conifer

Thinning stands to retain at least 40 percent of the existing basal area comprised of the largest trees while: retaining 5 percent or more of the total treatment area in trees 6 to 24 inches; and retaining at least 40% canopy would reduce the number of trees per acre, basal area, and stand density index. Because of the denser canopies in thinned Sierran mixed conifer stands, prescribed fire following thinning would further reduce the number of trees per acre. Basal area would be within the range recommended to minimize insect-related mortality. SDI would be near the maximum level recommended to sustain forest health during drought conditions, but would not fall within the desired range. Although SDI would remain higher than desired, resultant stands would be more resilient to drought, insects, disease, and wildfire than they are currently. The diameter distribution and the proportion of TPA and BA per acre by species of Sierran mixed conifer stands following treatment reflect the desired condition for less dense stands with a greater proportion of larger diameter trees managed for the shade-intolerant, drought-tolerant, and fire-resistant pine component (Figures 5 and 6).

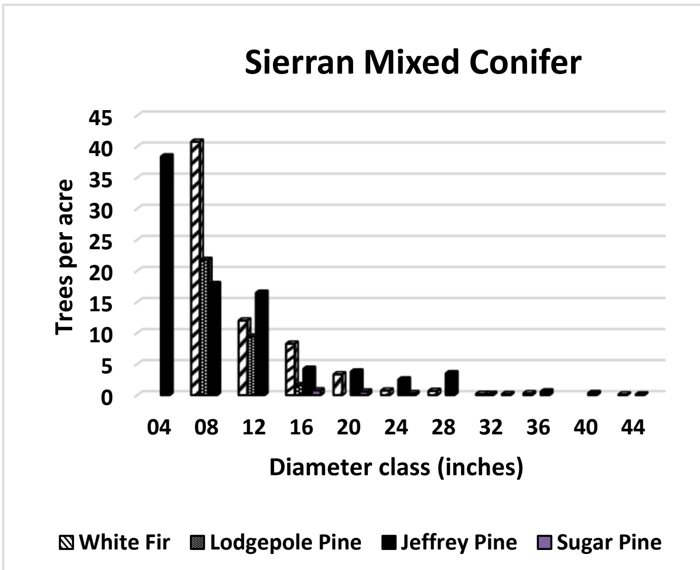


Figure 5. Distribution of trees per acre by diameter class and species for Sierran mixed conifer stands in the Bootsole project area following treatment.

Before treatment, shade-intolerant white fir accounted for over half of the number of trees per acre and basal area in Sierran mixed conifer stands. As in eastside pine stands, abundant small lodgepole pine growing in low elevation, moist areas comprised over one quarter of the stand density but less than 10% of the basal area. Jeffrey pine contributed 8% of stems but a third of the basal area. Few large sugar pines contributed 2% of the basal area before treatment but 3% after treatment. Large incense cedar contributed less than one percent to TPA and BA. The allocation of basal area across species following treatment would more closely resemble historic basal area by species modeled for fire dependent yellow pine–mixed-conifer forest at a similar elevation (Kercher and Axelrod (1984) as adapted by Safford and Stevens 2017). The sugar pine portion of basal area would be close to the historic level of 4%; however, the fir component would be disproportionately large and the pine and incense cedar components less than would have been present historically.

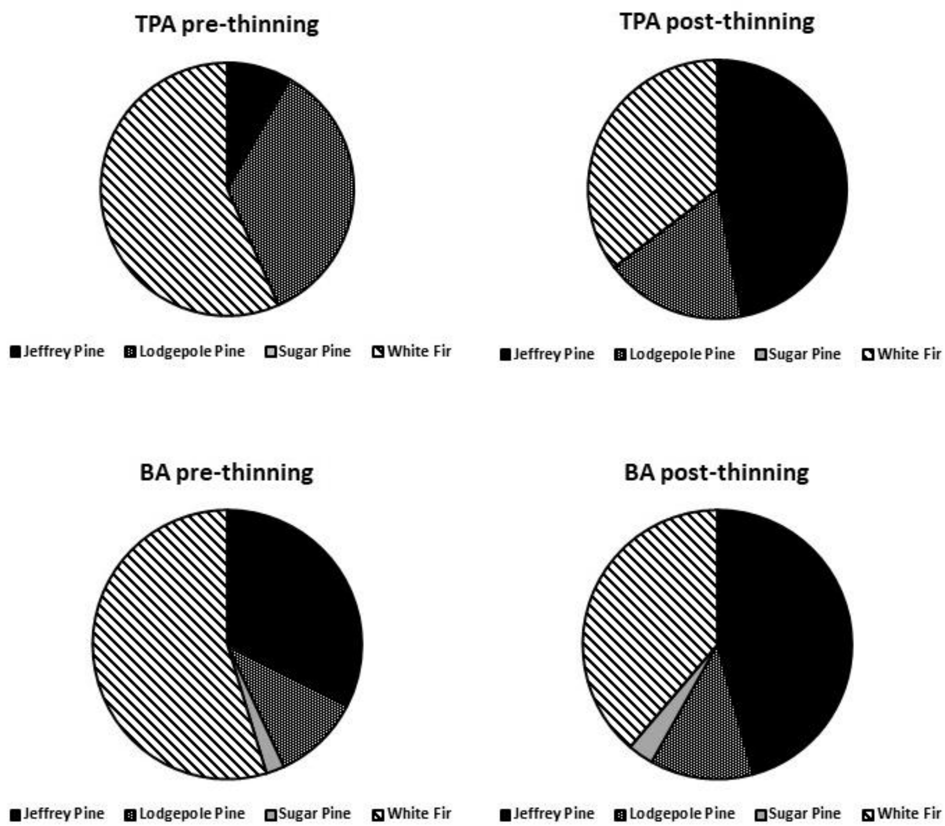
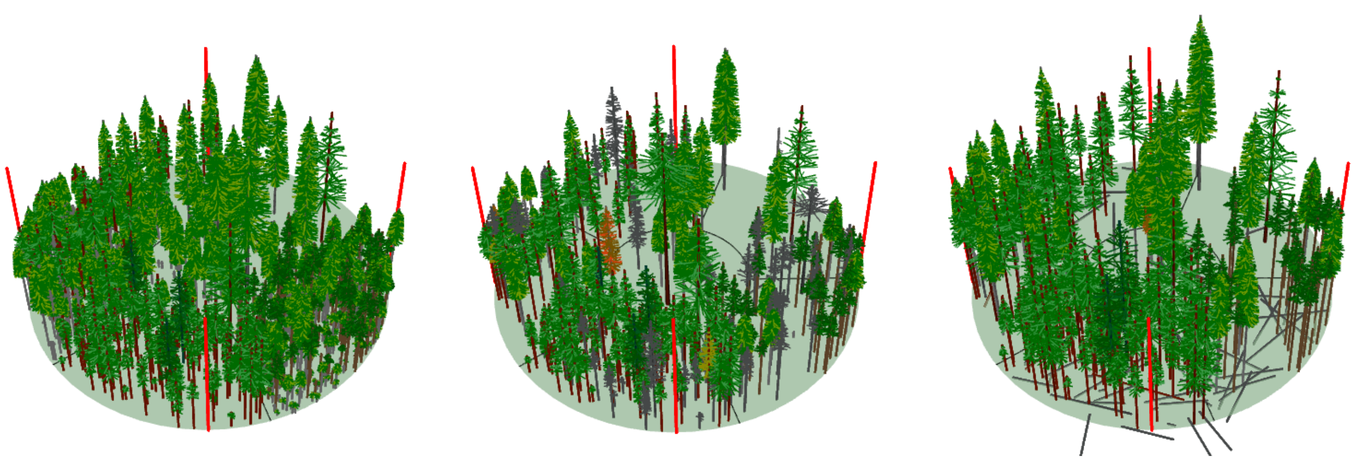


Figure 6. Proportion of trees per acre and basal area (ft2/acre) in Sierran mixed conifer stands within the Bootsole project area pre- and post-treatment

Stands would be made up of larger trees, on average, that would be more resilient to fire. Canopy cover would be reduced to no less than 40% as directed. CWHR type would change from 3M to 4M immediately after treatment and would transition to 4P briefly if prescribed burning resulted in the degree of mortality modeled by the Forest Vegetation Simulator. A visualization of the effects of thinning on Sierran mixed conifer stands can be seen in Figure 7.



Inventory 1 year post treatment 20 years post treatment

Figure 7. Visualization of Sierran mixed conifer stand structure at the time of inventory, one year post treatment, and 20 years post treatment.

The residual canopy cover and basal area constraints used to model the effects of the Bootsole Project on Sierran mixed conifer stands apply to mature forest habitat types (4M, 4D, 5M, 5D, and 6). However, there are no CWHR 5M or 5D in the project area and very little 4M or 4D within the Sierran mixed conifer type. The remainder of Sierran mixed conifer stands fall within size classes 2 and 3 or CWHR type 4P and there are no minimum canopy cover requirements for these types. In his evaluation of stand conditions with respect to forest insects and disease within the Bootsole project area, Cluck (2020) recommends that "most white fir and mixed conifer stands within the Bootsole project should be managed for the pine component as much as possible. This includes all white fir dominated stands with a ponderosa/Jeffrey pine component. This will likely require a change from the current mixed conifer or white fir stand typing in many areas to yellow or eastside pine, better representing historic species compositions and desired future conditions. Having the ability to significantly reduce stand density and the abundance of white fir is critical to successful ecological restoration within the project area." This recommendation is endorsed by the recommendation in the LRMP (USDA 1988) to convert "off-site" white fir stands to pine. Because of existing stand conditions, LRMP direction, and Cluck's (2020) recommendation, the effects of treating Sierran mixed conifer stands using the guidelines for eastside pine stands (i.e., retain 30% of the existing basal area with no canopy cover retention standards and guidelines) were also modeled. If all or a portion of Sierra mixed conifer stands were treated with the same standards and guidelines as eastside pine, the effects would be the same as detailed above for eastside pine stands (also see Table 2).

Aspen

Removing conifers, with the exception of legacy trees, from within aspen stands and where aspen occurs as a minor component would result in aspen stands with abundant small aspen and fewer aspen trees in larger diameter classes (Figure 8). Removing the conifer overstory would increase available light and greatly improve the growing conditions for established aspen trees and understory plant cover. The increase in sunlight reaching the forest floor would raise soil temperatures and increase photosynthetic rates allowing existing aspen suckers to thrive and stimulating sprouting. Full sunlight reaching the forest floor and would enhance any natural sucker production that is already occurring in declining aspen clones and in aspen buffer areas (Shepperd et.al. 2006). Conifer removal in areas buffering aspen stands has proven successful in increasing aspen regeneration in as little as three years post-treatment (Jones et al. 2005). Fencing would provide protection to young aspen shoots if needed to prevent excessive browsing. Protection of aspen ensures terminal leaders are free to grow and hastens the development of aspen into the mid- and overstory. The removal of nearly all conifers should reduce the rate of reinvasion and the subsequent need for follow-up treatments to remove conifer regeneration. The growth response of understory and overstory (aspen) to conifer removal would move this vegetation type towards the desired condition of restoring the species composition and structural diversity necessary to provide desired habitats and ecological functions. A visualization of the effects of conifer removal on aspen stands can be seen in Figure 9.

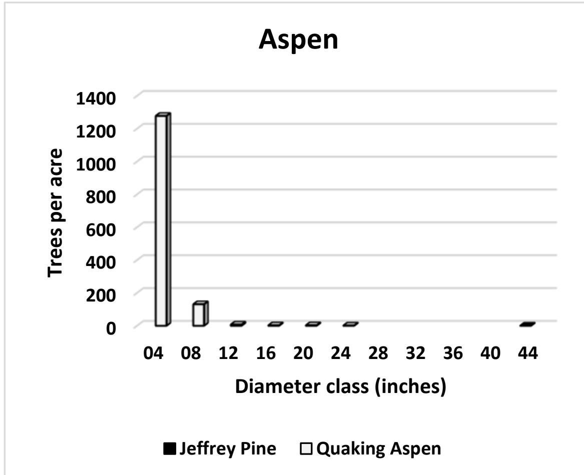


Figure 8. Distribution of trees per acre by diameter class and species for aspen stands in the Bootsole project area following treatment.

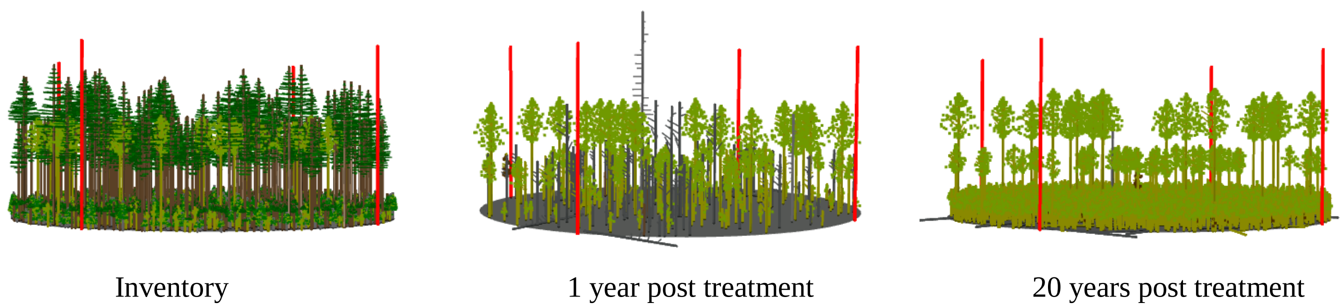
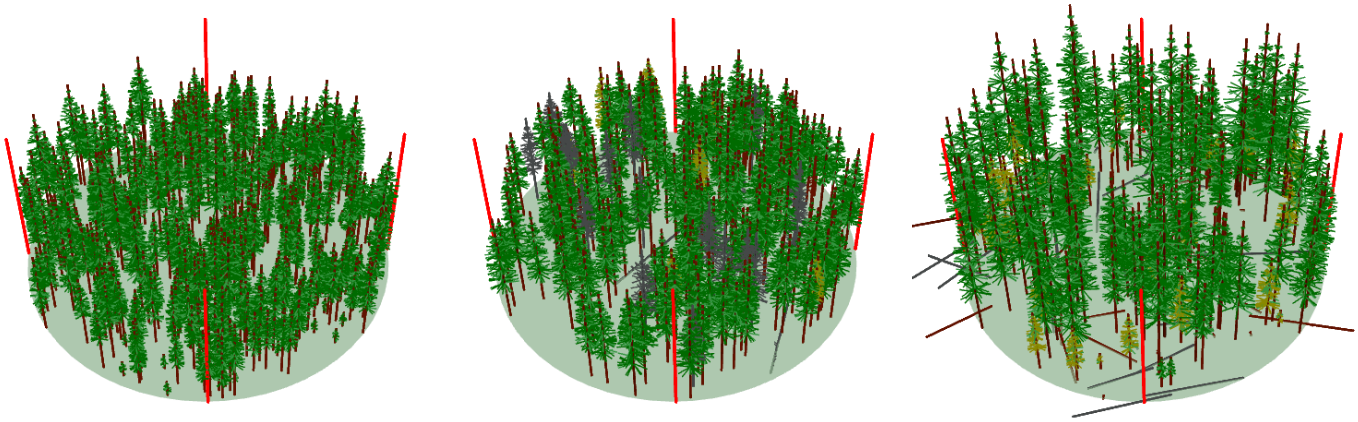


Figure 9. Visualization of aspen stand structure at the time of inventory, one year post treatment, and 20 years post treatment.

Mechanical Fuels

Removing forest fuels less than 11 inches in diameter from select pine stands would remove all white fir and lodgepole pine and would result in these stands initially meeting the desired conditions for TPA and BA, but not stand density index. Modeled SDI increases above 150 following thinning because only the smallest trees would be removed from stands with an otherwise fairly narrow diameter distribution and these stands are currently in the most vigorous growth period of their lifespan. The density of trees and uniformity in size would result in modeled BA over the desired target of 125 ft^2 per acre after 10 years. However, the reduction in stem density and retention of only drought-tolerant, fire-resistant pine would make these stands more resilient to insects, disease, drought, and wildfire than they are at present as reduced competition would result in better individual tree growth and vigor of remaining trees. Resultant stands would have larger trees on average and would transition from CWHR type 3M pre-treatment to 4P post treatment and 4M ten years post treatment. A visualization of the effects of mechanical fuels treatments on pine stands can be seen in Figure 10.



Inventory 1 year post treatment 20 years post treatment

Figure 10. Visualization of mechanical fuels treatment stand structure at the time of inventory, one year post treatment, and 20 years post treatment.

California Spotted Owl Protected Activity Center

Hand thinning to remove fuels less than 6 inches DBH from the California Spotted Owl (CSO) Protected Activity Center (PAC) and pruning limbs to a height of six feet would result in tree density, BA, and SDI that would exceed the levels consistent with the site's ability to sustain forest health during drought conditions. However, the desired conditions for CSO PACs are that they contain dominant trees at least 24 inches DBH and have at least 60-70% canopy cover. Because canopy cover would not be reduced in the PAC, and only small trees would be removed, prescribed fire following thinning would be expected to result in mortality of an equal number of trees in the 5-10- and 10-20-inch diameter classes. These would create higher levels than average of snags and, over time, downed woody debris which are desired habitat elements in the CSO PAC (USDA 2004). Basal area and SDI would remain above desired levels. Although stand density would remain higher than desired, the PAC would be somewhat more resilient to drought, insects, disease, and wildfire than it is currently. Treating the areas surrounding the CSO PAC will confer some protection against wildfire as the probability of crown fire originating in adjacent areas and spreading to the PAC will be reduced, while the vegetation in the PAC trends toward the desired condition of larger diameter trees and the canopy cover is remaining at or near the desired level.

CWHR type would change from 3M to 4D immediately after treatment and would transition to 4M following prescribed burning. Within 20 years following treatment canopy cover would increase and the PAC would be classified as 4D. Accelerating the development of these mature habitat types (4M and 4D) would provide more desirable CSO habitat on the landscape sooner than if the PAC was not treated. A visualization of the effects of thinning on the CSO PAC can be seen in Figure 11.

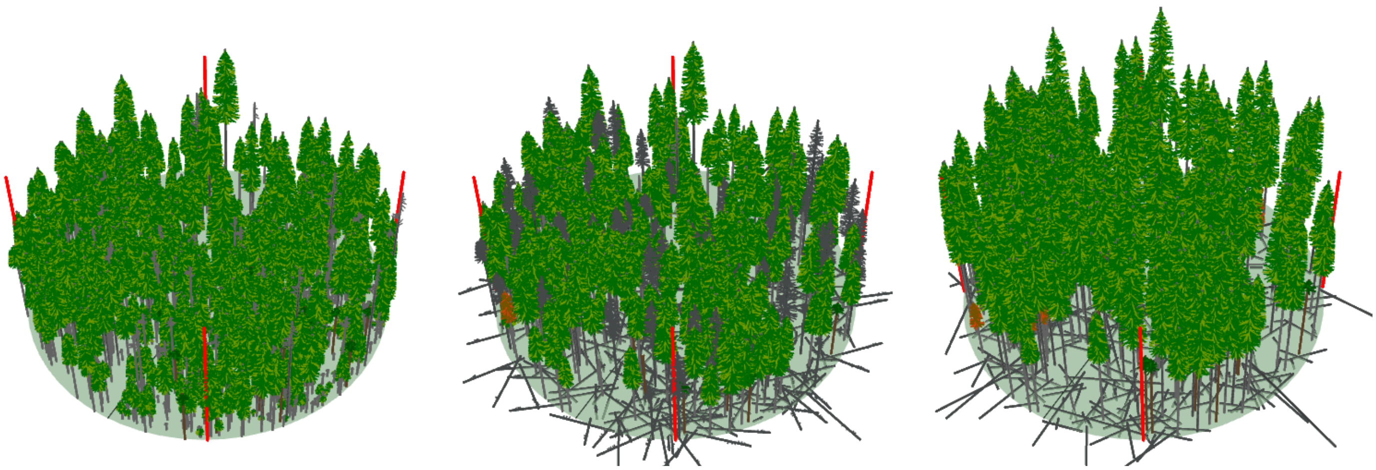


Figure 11. Visualization of California spotted owl Protected Activity Center stand structure at the time of inventory, one year post treatment, and 20 years post treatment.

Table 2. Values of indicators of stand structure and resilience, averaged across treatment and stand type, at time of inventory and for 20 years following implementation of the Bootsole Project.

Stand Type	Year	Trees per Acre		Basal Area (ft^2/acre)		Stand Density Index	
		Bootsole	***No Action***	***Bootsole***	***No Action***	***Bootsole***	***No Action***
Mechanical Thin Eastside Pine	Inventory	674	674	192	192	327	327
	Thin	74	657	69	199	99	337
	5 years post thin	53	611	74	216	102	359
	10 years post thin	53	555	84	230	114	375
	20 years post thin	53	452	105	250	138	392
Mechanical Thin Sierran Mixed Conifer*	Inventory	1082	1082	182	182	322	322
	Thin	185/ 87	1067	131/ 74	193	205/ 105	342
	5 years post thin	123/ 64	1006	127/ 79	218	186/ 109	385
	10 years post thin	122/ 64	945	143/ 89	241	206/ 121	421
	20 years post thin	120/ 64	782	176/ 110	281	244/ 145	472
Mechanical Thin Aspen	Inventory	2119	2119	190	191	364	364
	Thin	1426	2092	84	201	190	392
	5 years post thin	1391	1977	105	222	244	438
	10 years post thin	1357	1860	119	239	276	471
	20 years post thin	1263	1620	144	262	322	507
Mechanical Thin Fuels	Inventory	508	508	147	147	261	261
	Thin	117	500	113	159	180	279
	5 years post thin	97	465	121	180	183	308
	10 years post thin	90	416	137	196	200	325
	20 years post thin	76	307	162	212	222	330
Hand Thin California Spotted Owl PAC	Inventory	685	685	243	243	444	444
	Thin	347	674	232	257	397	463
	5 years post thin	257	637	209	286	346	500
	10 years post thin	253	599	237	311	382	531
	20 years post thin	245	542	295	365	453	596

*The second set of numbers for the Bootsole Project are model outputs if Sierran mixed conifer stands were treated with the same constraints as eastside pine stands.

Table 2 (continued)

Stand Type	Year	Quadratic Mean Diameter (in)		Percent Canopy Cover		CWHR Type	
		Bootsole	***No Action***	***Bootsole***	***No Action***	***Bootsole***	***No Action***
Mechanical Thin Eastside Pine	Inventory	8.6	8.6	50	50	3M	3M
	Thin	15.4	8.9	23	51	4S	3M
	5 years post thin	17.6	9.7	26	54	4P	3M
	10 years post thin	18.7	10.5	31	55	4P	3M
	20 years post thin	21.0	12.3	36	57	4P	4M
Mechanical Thin Sierran Mixed Conifer*	Inventory	6.4	6.4	51	51	3M	3M
	Thin	11.5/13.5	6.6	41/ 23	53	4M/ 4S	3M
	5 years post thin	13.9/16.3	7.2	38/ 25	56	4P/ 4P	3M
	10 years post thin	14.8/17.3	7.7	41/ 27	60	4M/ 4P	3D
	20 years post thin	16.5/19.1	8.9	46/ 32	65	4M/4P	3D
Mechanical Thin Aspen	Inventory	4.8	4.8	48	48	2M	2M
	Thin	3.9	5.0	28	49	2P	2M
	5 years post thin	4.4	5.3	25	54	2P	2M
	10 years post thin	4.8	5.7	26	55	2P	2M
	20 years post thin	5.5	6.4	28	60	2P	3D
Mechanical Thin Fuels	Inventory	8.9	8.9	42	42	3M	3M
	Thin	13.8	9.4	36	44	4P	3M
	5 years post thin	15.5	10.7	37	47	4P	3M
	10 years post thin	17.0	11.9	40	51	4M	4M
	20 years post thin	20.0	14.7	44	53	4M	4M
Hand Thin California Spotted Owl PAC	Inventory	8.1	8.1	59	59	3M	3M
	Thin	11.1	8.3	60	60	4D	3D
	5 years post thin	12.2	9.1	54	62	4M	3D
	10 years post thin	13.1	9.8	56	63	4M	3D
	20 years post thin	14.9	11.1	60	69	4D	4D

*The second set of numbers for the Bootsole Project are model outputs if Sierran mixed conifer stands were treated with the same constraints as eastside pine stands.

Alternative 2 – No Action

If the project were not implemented, mortality related to drought, disease, and insects would continue to occur as well as recruitment of shade-tolerant species. Stands would remain dense, particularly in the smaller diameter classes in terms of trees per acre, basal area, and stand density index (Table 2). Forest health would continue to decline and additional episodic mortality would be expected in times of drought and insect infestation.

High tree densities would persist, thereby reducing growth rates and tree vigor, and increasing risk of mortality due to inter-tree competition and increased incidence of insect activity. High densities of small trees may cause competition for soil moisture and nutrients, which could contribute to increased stress on larger, older trees. Over time, this would contribute further to a species conversion from shade-intolerant species dominance to that of shade-tolerant species dominance.

In the absence of treatment, stands within the project area would continue to be at a high risk for insect infestations and disease infections as stand growth and vigor continue to decline. Dwarf mistletoe-infected trees in the overstory would continue to infect understory trees and adjacent stands. Stand health would continue to decline in overstocked aggregations of trees within moderately stocked and densely stocked stands, eventually resulting in individual tree mortality. Mortality would increase the fuel loading.

The current overstocked condition in most stands, as well as the overabundance of white fir in previously pine-dominated stands, would continue to facilitate high levels of insect and disease activity. Large-scale bark beetle outbreaks would likely occur periodically in response to extended drought periods. In the interim, older Jeffrey, sugar, and ponderosa pine would continue to succumb to disease, drought and bark beetle attacks and slowly be replaced by dense stands of younger shade-tolerant trees. White fir would continue to succumb to fir engraver beetles after being weakened by Heterobasidion root disease. Fuel loads would continue to increase creating a high risk of high intensity and stand replacing fire across all forest types.

The health of aspen stands and meadows would continue to decline as would the area covered by these vegetation types. Aspen regeneration would be suppressed by shading conifers and conifers would continue to spread into meadows. Conifers within aspen stands would follow the same pattern of declining vigor, increased mortality, increased accumulation of forest fuels, and increase susceptibility to catastrophic wildfire as other conifer stands in the project area.

Maintaining the existing stand structure would favor shade-tolerant species such as white fir. There would be little opportunity for the naturally dominant pine species to re-establish and regenerate themselves, except what may occur through natural large-scale disturbance events such as wildfire.

The project area would continue to be dominated by closed-canopy, early-seral forested stands. These stands, best characterized by CWHR size class 3 and canopy density class moderate (M), contribute to landscape homogeneity due to their abundance and connected arrangement. Because such stand structure has increased vulnerability to high-severity fires, insect outbreaks, and landscape level drought-induced mortality, a homogenous (same species or structure) occurrence of these closed-canopy, early-seral stages across the landscape is unstable and less resilient to forest disturbances.

At the stand level, similar to what has occurred at the landscape level, the combination of past management activities, fire exclusion, and extensive drought-related mortality has created relatively homogeneous areas typified by small, even-aged trees existing at high densities. These trends would continue without treatment. Trees in suppressed and intermediate crown classes would continue to provide ladder fuels into the overstory crown canopy. Existing conditions across the project area, i.e., high numbers of trees per acre with dense understories and high canopy cover, indicate high fuel ladder potential and interlocking crowns capable of sustaining crown fires.

Adaptiveness to Climate Change

The Bootsole Project is a landscape-level designed project which proposes to improve the resilience of forested landscapes to disturbances such as drought, insects, disease, and wildfire. Many of the same techniques (e.g., reducing the number of trees per acre, basal area, stand density index, and canopy cover) used to improve forest resilience to these stressors are the same techniques needed to provide resilience in the face of climate change.

Under future climate scenarios, forests in the western U.S. are predicted to experience warmer, drier climates than they do currently (Meehl et al. 2007). As a result, competition for water will increase in most areas, and what are currently considered drought conditions will become more common. Trends in increased frequency and size of wildfires (NASA 2018, AAAS 2020) are expected to continue.

The Bootsole Project proposes to address these anticipated effects of climate change by: thinning trees to reduce competition for water thereby improving the health and vigor of remaining trees and improve their ability to sequester carbon; preferentially removing white fir which is not adapted to the current annual precipitation in the project area and which is susceptible to wildfire; preferentially retaining drought- and fire-resistant pine species; and reducing the canopy cover to reduce the probability of stand replacing wildfire. The Bootsole Project's targets for residual basal area and stand density index have been shown to make stands more resistant to attack by insects and mortality in times of drought (Cochran 1998; Egan et al. 2006; Oliver 1995, 1998; Powell 1999).

Although relatively unexplored in natural forests, a potential approach to minimize the potential consequences for tree populations due to climate change is the reduction of forest basal area. Basal area reduction has been shown to effectively increase water availability to residual trees, improving tree resistance and resilience to drought and decreasing mortality rates in experimental settings (Bradford and Bell 2017). On the Lassen National Forest, even large, old trees responded to restoration thinning treatments (Hood et al. 2017).

Implementation of the Bootsole Project will result in the project area becoming more resilient to disturbance, including climate change. Treatment prescriptions are based on the currently best available science; however, it may be prudent to incorporate more aggressive thinning treatments into future project design to evaluate their efficacy under a variety of natural climate variation.

Compliance with Forest Plan and Other Relevant Laws, Regulations, Policies and Plans

The Bootsole Project meets the National Forest Management Act (NFMA) of 1976, including its amendments to the Forest and Rangeland Renewable Resources Planning Act of 1974 and the 1988 Plumas Land and Resource Management Plan. The NFMA states that it is the policy of the Congress that all forested lands in the National Forest System be maintained in appropriate forest cover with species of trees, degree of stocking, rate of growth, and conditions of stand designed to secure the maximum benefits of multiple use sustained yield management in accordance with land management plans.

References

American Association for the Advancement of Science (AAAS). 2020. Wildfire Trends in the United States. Available at: https://www.sciline.org/evidence-blog/wildfires

Bradford, JB and DM Bell. 2017. A window of opportunity for climate-change adaptation: easing tree mortality by reducing forest basal area. Frontiers in Ecology and Environment. 15(1): 11–17.

Cochran, PH. 1998. Examples of Mortality and Reduced Annual Increments of White Fir Induced by Drought, Insects, and Disease at Different Stand Densities. USDA Forest Service, Pacific Northwest Research Station. Research Note PNW-RN-525

Cluck, Daniel R. 2020. Evaluation of stand conditions with respect to forest insects and disease within the Bootsole project, Plumas National Forest (FHP Report NE20-02). Available in the Project Record.

Dunning, D. and L.H. Reineke. 1933. Preliminary yield tables for second-growth stands in the California pine region. USDA Forest Service, Washington DC. Technical Bulletin. N-354.

Egan JM, Sloughter JM, Cardoso T, Trainor P, Wu K, Safford H, Fournier D. 2016. Multi-temporal ecological analysis of Jeffrey pine beetle outbreak dynamics within the Lake Tahoe Basin. Population Ecology 58:441–462.

Hood, S.M., Cluck, D.R., Jones, B.E., and Pinnell S. 2017. Radial and stand-level thinning treatments: 15-year growth response of legacy ponderosa and Jeffrey pine trees. *Restoration Ecology*. doi:10.1111/rec.12638

Jones, B. E., Rickman, T. H., Vazquez, A., Sado, Y. and Tate, K. W. 2005. Removal of encroaching conifers to regenerate degraded aspen stands in the Sierra Nevada. Restoration Ecology, 13(2): 373–379.

Kercher, J.R.; Axelrod, M.C. 1984. A process model of fire ecology and succession in a mixed-conifer forest. Ecology. 65: 1725–1742.

LANDFIRE Rapid Assessment (LFRA) Reference Condition Model. 2005. Potential Natural Vegetation Group R1PIJE Jeffrey Pine. Available at: www.fs.fed.us/database/feis/pdfs/PNVGs/California/R1PIJE.pdf Accessed: January 25, 2021.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao, 2007: Global Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

National Aeronautics and Space Administration (NASA). 2018. Six trends to know about fire season in the western U.S. Results of the NASA-funded Rehabilitation Capability Convergence for Ecosystem Recovery (RECOVER) analysis of more than 40,000 fires from Colorado to California between 1950 to 2017. Available at:

https://climate.nasa.gov/blog/2830/six-trends-to-know-about-fire-season-in-the-western-us/

North M, Innes J, and Zald H. 2007. Comparison of thinning and prescribed fire restoration treatments to Sierra mixed-conifer historic conditions. Canadian Journal of Forest Research. 37:331–342.

Oliver, W. 1988. Ten-year growth response of a California red and white fir saw timber stand to several thinning intensities. Western Journal of Applied Forestry 3:41–43.

Oliver, W. W. 1995. Is self-thinning in ponderosa pine ruled by *Dendroctonous* bark beetles? *In* Proceedings of the 1995 National Silviculture Workshop, General Technical Report RM-GTR267, pp. 213-218. USDA Forest Service, Fort Collins, Colorado.

Powell, D.C. 1999. Suggested Stocking Levels for Forest Stands in Northeastern Oregon and Southeastern Washington: An Implementation Guide for the Umatilla National Forest. USDA Forest Service, Pacific Northwest Region Technical Publication F14-SO-TP-03-99, April 1999.

Reineke, L. H. 1933. Perfecting a stand density index for even aged forests. Journal of Agriculture Research 46:627-638.

Safford, HD and JT Stevens. 2017. Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA. Gen. Tech. Rep. PSW-GTR-256. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 229 p.

Shaw, J.D. 2006. Reineke's Stand Density Index: Where are we and where do we go from here? Proceedings: Society of American Foresters 2005 National Convention. October 19-23, 2005, Ft. Worth, TX. Society of American Foresters, Bethesda, MD.

Shepperd, W.D., P.C. Rogers, D. Burton, and D.L. Bartos. 2006. Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada. USDA Forest Service General Technical Report RMRS-GTR-178. 122p.

Taylor, AH. 2004. Identifying forest reference condition on early cut-over lands, Lake Tahoe Basin, USA. Ecological Applications. 14(6): 1903-1920.

United States Department of Agriculture (USDA). 1988. Plumas National Forest Land and Resource Management Plan. Available at: Plumas National Forest - Planning (usda.gov)

USDA. 2004. Final Supplemental Environmental Impact Statement, Sierra Nevada Forest Plan Amendment, Record of Decision. USDA Forest Service, Region 5, Vallejo, CA. 72p.

Wenger, K. F. 1984. Forestry Handbook, Second Edition. John Wiley and Sons Incorporated. New York, NY. 1335 p.